

This section provides an overview of the study, from the purpose and objectives to the findings and recommendations.

1.1 PURPOSE AND OBJECTIVES

The overall purpose of this study was to determine baseline construction practices of newly constructed homes following the implementation of the RBES code, and to assess the efficiency of lighting and common appliances being installed in these homes. Although not an exhaustive impact analysis of the efficiency program impacts, this study also highlights the effects of the utility DSM programs of the late 1990's and the ongoing efficiency programs currently implemented by Efficiency Vermont efficiency activities, as appropriate.

This study was accomplished through the following four strategies:

1. Determine current construction practices based on nearly 160 onsite surveys of newly constructed houses.
2. Assess the level of code compliance based on the onsite survey data and investigate the reasons for noncompliance.
3. Measure the saturation levels of efficient lighting and appliances.
4. Compare current construction practices to construction practices prior to the RBES code.

1.2 SAMPLE DESIGN

The general strategy for the sample design was a simple random sample of all newly constructed one and two family homes in the state to provide a basis for statistically valid estimation of statewide code compliance. The sample was designed to provide a total of 160 visits, and 158 site visits were completed.

A nested sampling approach was employed. First, potential participants were asked to respond to the telephone survey, and then solicited for the on site survey after completion of the phone questionnaire. Seventy-six of the 158 survey participants were solicited through this nested sampling approach, and the rest were contacted directly from the remaining names in the sample frame, i.e., those who could not be reached initially or did not want to participate in the telephone survey.

1.3 BUILDING DATA ANALYSIS APPROACH

The analysis is based on site surveys of 158 homes for thermal shell characteristics and lighting, and 159 homes for appliances. The site visit consisted of collecting detailed information on all aspects of the thermal shell, equipment and appliances, and performing a blower door test.

There are three verification methods for RBES code compliance, i.e., the VTCheck software, meeting the Home Energy Rating standard and the prescriptive approach. For most homes in the study, compliance was determined by the VTCheck methodology. Compliance for the nineteen homes that went through the Vermont Star Homes program and received energy ratings was assessed by the Home Energy Rating standard. Homes that failed to meet compliance by either of these methods also failed the prescriptive path.

For the 139 homes where the blower door test was done as part of the site visit, the test and calculation of the natural air changes per hour were designed to be consistent with ASHRAE standards for comparison with the ASHRAE ventilation standard. In nineteen homes, the builder participated in the Vermont Star Homes and the home received an energy rating. For these homes, the blower door test was conducted by program staff and the methodology for calculating the natural air changes per hour was slightly different.

1.4 FINDINGS

The results of this study show some impressive gains in some common building practices. In comparison to the 1995 baseline study, heating system efficiencies have improved, the saturation of high efficiency windows has increased from about 70% to 80% for low E and from 38% to 50% for gas filled, and the most inefficient DHW systems (tankless coils) have virtually disappeared from new homes, down from almost 30% in 1995 to 3% in 2002. The potential impact of these efficiency gains, however, is offset by some other significant trends. The pressure to build larger homes appears to be continuing, and the new homes in this sample, particularly the large homes, tend to have a much larger proportion of glazing than found in the previous study. Excessive oversizing of heating equipment is still a common practice.

While most homes are built at a midlevel of efficiency or higher, there are still a few homes being constructed with little regard to basic efficiency standards. About a quarter of the sample failed to come within 30% of the RBES compliance standard. In one-third of these homes, the high window glazing percentage was a contributing factor to the failure to meet code. Owner-built and manufactured homes account for more than half of this bottom stratum.

1.4.1 House Size

The new homes in the survey were large, averaging over 2,500 square feet with a 95% confidence interval of 2,284 to 2,545 square feet. The average home had over 800 square feet per occupant. A contributing factor to the considerable size of the living area was the prevalence of finished area in the basement.

The large, and sometimes excessive, house sizes have two major ramifications. First, and most obvious, is that larger homes use more energy, and this additional energy usage cannot be entirely offset by increasing the efficiency of the homes. The second implication is that the combination of large homes and few occupants makes it easier for these homes to meet the ASHRAE ventilation standards.

1.4.2 Code Compliance

A majority of the homes (58% +/- 8%) passed the RBES code using the VTCheck software methodology or energy rating data where available. This result represents a substantial improvement over the 1995 baseline study, in which 35 to 40% of the homes were estimated to pass the RBES standards. The major reasons for non-compliance with the code were the absence of foundation insulation and the high ratio of glazing-to-wall-area.

Although 58% passed, a low proportion (18%) had completed RBES certification forms in their homes.¹ Four of the 28 homes with RBES certificates displayed actually failed the VTCheck criteria by a wide margin.

The relatively high percentage of homes passing the standard must be balanced against the reality of the standard building practices. Some homes that passed through the VTCheck methodology did not meet some basic efficiency standards, such as insulation levels of R-38 or higher in attic flats or R-30 in attic slopes. Also, the code does not cover some aspects of energy efficiency, such as air infiltration standards and heating system sizing.

1.4.3 Manufactured Housing

Manufactured housing accounts for a substantial part of the market, at least 17% +/- 6% at the 95% confidence level. It is possible that this proportion is understated. Although this component of the housing stock is commonly produced to meet minimum code requirements when it leaves the factory, there is evidence to suggest that the thermal efficiency of these homes as installed on site is lower than site built homes.

¹ It is possible that the RBES certification was submitted to the Vermont Department of Public Service or the town clerk for some homes, but certification through these mechanisms has been quite low.

1.4.4 Thermal Shell and Ventilation

Insulation and glazing characteristics were similar to the 1995 baseline study with about 65% of the homes (90% for walls) meeting or exceeding the minimum prescriptive RBES standard. The one exception was a significant increase in the number of homes with foundation insulation from less than one half of the homes in 1995 with R-10 or more, to almost two-thirds of the homes meeting the minimum prescriptive RBES standard of R-10 in the current study. Other types of basement and foundation components, such as slabs, exposed floors and floors over unconditioned space, were underinsulated in most of the homes with these components.

Efficiency programs appear to be a major driver in promoting the mechanical ventilation in new homes. Whole house ventilation is required to meet the Vermont Star Home designation, and exhaust fans with timers are frequently recommended as a cost effective way to meet this standard. Participants in the utility or Vermont Star Homes programs were much more likely to install mechanical ventilation, including exhaust fans on timers (70% of homes as compared to 15% of the homes of nonparticipants).

Homes were tightly built, with two-thirds of the sample homes having a natural air changes per hour rate of .31 or less. Although the homes are tight, they generally meet the ASHRAE Standard 62 guidelines for air flow at the current occupancy levels.²

1.4.5 Heating and DHW Systems

Oil was the predominant fuel for both space and water heating, and the saturation of low efficiency tankless coil water heating systems dropped precipitously from almost 30% in the 1995 study to 3% in the current one. A large majority of the heating plants were in the mid to upper range of efficiencies. Most homes with boilers also had integrated water heating. As shown in the 1995 baseline study, heating systems were consistently oversized to an excessive degree. The median oversizing was 81%, approaching twice as much heating output as required by the load.

1.4.6 Lighting and Appliances

The average number of fixtures per home increased markedly from the 1995 study, from 25 to 34. The penetration of CFL lighting among participants of the statewide or utility efficiency programs is high, in terms of the percentage of homes using this technology (80%), the number of CFL fixtures installed per home (50% of homes with four or more) and the incidence of installation in high use locations. This result indicates that the rebates for CFL fixtures and

² Standard 62 requires 15 cfm per person. Consequently, the level of occupancy of the house has an impact on the air flow requirements.

technical assistance provided by the efficiency programs have been effective at promoting these products.

Among survey respondents who did not participate in any efficiency programs, the penetration of CLF fixtures was much lower in all respects, leading to the conclusion that CFL fixtures have still not achieved acceptance in the general market.

The penetration of Energy Star appliances was reasonably high, with 47% of clothes washers, 36% of dishwashers and 27% of refrigerators meeting the Energy Star criteria at the time of purchase. Program impact on appliance purchase was mixed, possibly reflecting a lesser degree of promotion of Energy Star appliances through the program prior to 2001. Central air conditioning was found in 6% of homes, the same saturation rate as hot tubs.

1.4.7 Comparison of On Site and Telephone Responses

By comparing the overlapping group of respondents who participated in both the on site and the telephone surveys, we were able to assess the comparability of the homes reflected in the two studies and evaluate the telephone responses in a few key areas. The two surveys appear to be quite similar in regard to house size, RBES compliance and participation in efficiency programs. This comparison also uncovered a number of areas where homeowner telephone responses did not correspond well with the results of the on site survey. The largest discrepancy related to electric water heating. While the on site survey concluded that 8% of the homes had an electric water heater, the results of the telephone survey indicated 25%. Comparison of the overlapping group showed that the homeowners' responses were largely unreliable for this piece of information, with thirteen out of seventeen incorrect responses.

For a number of other house characteristics, the discrepancies between the telephone and on site survey responses were in the range of 15 to 30%. On average, the telephone responses underestimated house size by about 15 to 20%, with owners of smaller homes (under 2,300 square feet) providing reasonably accurate responses and owners of large homes (over 2,300) consistently underestimating the size of their homes. There tended to be some confusion among homeowners regarding the difference between primary and secondary heating systems and between natural gas and propane. Homeowners on average were more likely to state that they heat with a forced air system, although the auditor identified a hydronic system. When the responses from the overlapping group were corrected by the confirmed data from the on site visit, the distribution of house sizes, fuel types and heating system types for this subset corresponded well with the results of the on site survey as a whole.

As is consistent with the finding of similar studies in other states, many homeowners tended to identify their appliances as "energy efficient" although a smaller percentage purchased Energy Star models. While two-third to three-quarters of homeowners identified their appliances as "energy efficient," Energy Star appliances were verified in about one-third to one half of the homes.

The last data point compared was manufactured housing. Although both the telephone and on site survey results indicate that about 17% of the new homes were manufactured housing, it is possible that both surveys underestimated the penetration of this type of construction. In the overlapping group, homeowners underrepresented their homes as manufactured homes by about 30% on average. For the on site survey, “manufactured home” was not a specific data point on the survey form, and these homes were identified from auditors’ notes and builder information, leaving the possibility that some manufactured homes could have been missed. Consequently, the 17% should be seen as a lower boundary of the penetration manufactured homes.

1.5 RECOMMENDATIONS

This section is divided into three parts: recommendations for future efficiency efforts in the residential new construction market, policy implications, and suggestions for the next round of evaluation efforts in this market.

1.5.1 Efficiency Potential

This study highlights a number of areas for potential efficiency improvements. The fact that 42% of the homes failed to meet the RBES standard, and about 30% failed by a substantial margin (more than 10%), emphasizes the importance of continuing to offer code support. Approximately half of the homes failing to meet the RBES standard by more than 10% were either owner-built or manufactured housing, indicating that efficiency efforts need to be designed to reach these groups. Efforts to improve the efficiency of manufactured housing should have a two pronged approach, with one set of initiative to encourage manufacturers to produce homes above the minimum standard and the second to promote efficiency building practices among the owners and builders who install the homes on site.

There are a few specific components of common construction practice that could be improved. With 73% of the homes built with 16" on center 2 x 6 wall construction, continuing program efforts to promote the use of 24" stud spacing in 2 x 6 walls, engineered corners and R-21 fiberglass would be warranted. This study also points to the need to continue to stress the importance of complete foundation insulation, including slab edges.

The excessive heating system oversizing shown to be common among the surveyed homes also presents opportunities for efficiency improvements. While recommended practice by ASHRAE standards is to oversize heating equipment by 25%, the median oversizing among the surveyed homes was 81%. Efficiency efforts would have to be targeted to heating contractors and attempt to address the causes for the current practice.

Efficiency programs to date have been shown to be making solid progress in promoting efficient lighting and whole house ventilation using exhaust fans. Their track record on other energy star appliances appears to be more mixed. The next challenge is to influence the purchase and installation of these efficient products on a wider scale.

A final issue for consideration in program implementation is the few homes (4) in which the homeowners believed the homes had received energy ratings through the program, but in actuality had not. Program implementers need to be aware of the balance between maintaining good relations with contractors and ensuring the integrity of their program.

1.5.2 Policy Implications

The trend toward larger homes with a higher percentage of glazing is likely to increase overall energy use to a far greater degree than can be offset by efficiency improvements. This pattern overshadows the overall goal of reducing energy usage, and cannot be effectively addressed through efficiency programs. While specific regulations to restrict house size are not likely to be feasible or desirable at this time, this trend should be considered in the context of state regulation and policies. One interesting finding of the survey was that Act 250 homes tended to be smaller on average than homes that were not subject to Act 250, although Act 250 does not have any specific size regulations. It is also entirely possible that a downturn in the economy will have an impact on the new construction market and the size and characteristics of new homes.

This study also points to a few areas for potential code enhancements. While a majority of homes complied with the RBES code, there were still 42% that did not, and 30% that failed by a substantial margin. While these results may be considered to be reasonably good for a state with no code enforcement, they also indicate the need for continuing education and consideration of potential enforcement strategies. Program efforts to assist builders with RBES compliance may be providing critical services to this market segment. However, attempting to combine the efficiency program with enforcement may lead to deteriorating relationships with contractors. Since program success is highly dependent on developing and maintaining strong and positive relationships in the building community, coupling efficiency program efforts with enforcement strategies should be avoided.

Another result of this study indicates that the VTCheck software or prescriptive standards for insulation and heating equipment do not directly address some of the current lapses in building practices. Currently, the RBES code does not cover some relevant areas associated with the installation of insulation or heating system sizing. Also, the VTCheck software incorporates trade offs that allow homes to pass with substandard attic insulation. One approach would be to replace the VTCheck software with the prescriptive and performance-based standards. This approach would prevent homes from meeting the code standards with substandard insulation and be easier to administer, although fewer homes in the current study would have passed using this method.

This study indicates that it should be possible to raise the minimum AFUE requirements for furnaces and boilers, and to increase the windows requirements to a minimum requirement of low E and argon. Since integrated DHW tanks have become the rule, an increase in the required efficiency of DHW could move along the elimination of the low efficiency tankless coils.

Vermont could also consider taking a similar approach to Massachusetts and strengthening the other code requirements, such as maximum sizes for heating equipment, improved installation standards for insulation and a minimum standard for DHW efficiencies above the federal minimum code requirement. If these elements are added to the RBES code, careful consideration should be given to tracking compliance and other enforcement strategies.

1.5.3 Recommendations for Future Evaluation Efforts

The approach of investigating the market from various perspectives, as proposed in the 1995 baseline study, was used to good advantage in the current round of evaluation activities. The combination of the telephone and builder surveys conducted by Xenergy and the on site survey results presented in this document yielded a more complex picture of the market place, and this approach should be employed again for the next round.

The primary area for potential adjustments may be in the objectives and implementation of the on site surveys. In this study, a major goal of the on site surveys was to determine RBES compliance by use of the VTCheck software. This approach required substantial time and effort in collecting the data for this task alone, leaving little possibility of investigating other issues.

The comparison of the telephone survey responses to the on site verification may also be useful for refining the homeowner telephone survey. This comparison has highlighted specific areas where the homeowner telephone responses were more or less reliable, and can be used to focus the next telephone survey on the areas most likely to yield reliable results.

1.5.3.1 Approach to On Sites

We recommend revisiting the overall strategy for the next on site survey. Measuring and documenting the areas and characteristics of the attic, walls, windows and other building components for determining compliance through the VTCheck software comprised a very large and time-consuming part of the site visits. This decision to collect this detailed information limited the possibilities of investigating other issues.

Input from field staff and other sources point to areas beyond insulation levels where further investigation is warranted. These include point sources of indoor air pollutants such as garages and unvented appliances, DHW equipment and configuration, duct balancing and sealing, lighting levels and combustion safety.

In the next round, one approach would be to record only the insulation levels and quality of installation, but not measure the areas. This single change would tremendously reduce the amount of time spent on this component of the site visits and open up the possibility of collecting data to evaluate lighting levels, indoor pollutants, wall construction details, etc. The insulation levels could be checked against the RBES prescriptive requirements to assess compliance levels, for homes without energy ratings.

1.5.3.2 Questions for the Next Round

This study has illuminated some areas of building construction that should be further investigated in the next round. For the next study, we should consider adding the following questions.³

What is the actual penetration of manufactured homes among new homes?

Are manufactured homes less efficient than site built homes? If so, where is the potential for efficiency improvements?

Are homes overlit?

Is indoor air quality a problem in new homes?

Are there common issues with combustion safety?

Are heating and DHW systems correctly (and efficiently) configured and installed?

Are there common practices in the installation of insulation that effectively reduce the R-value?

What are common wall construction practices?

Are ducts properly balanced and sealed in homes with furnaces?

Are central A/C units properly sized?

Some of these issues were identified in the 1995 baseline study also, but as discussed above, the focus on measuring and recording areas for each building component limited our ability to address these issues.

³ Many of these issues were highlighted by the subcontractors who performed the site visits. Their comments are included as Appendix 2.